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NATIONAL BUREAU OF STANDARDS REPORT

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QUARTERLY PROGRESS REPORT NO. 1
SEPTEMBER 17 TO DECEMBER 31, 1971

Title of Project

NONMETALLIC COATINGS FOR CONCRETE REINFORCING BARS

Sponsored by
Federal Highway Administration

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
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January 24, 1972

NBS REPORT
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SEPTEMBER 17 TO DECEMBER 31, 1971

Title of Project

NONMETALLIC COATINGS FOR CONCRETE REINFORCING BARS

Sponsored by
Federal Highway Administration
U. S. Department of Transportation
Washington, D. C. 20590

by
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Approved for public release by the director of the National Institute of Standards and Technology (NIST) on October 9, 2015

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NATIONAL BUREAU OF STANDARDS

PREFACE

This is the first progress report for the project Nonmetallic Coatings for Concrete Reinforcing Bars. The period from September 17 to December 31, 1971 is included in this report. Subsequent reports will be issued on a quarterly basis.

Quarterly Progress Report No. 1
(September 17 to December 31, 1971)

1. Study Identification: Order No. 2-1-0614

   Title: Nonmetallic Coatings for Concrete Reinforcing Bars.

2. Date Work Started: 9/17/71

   Date of Report: 12/31/71

3. Research Agency: National Bureau of Standards

4. Background

The early deterioration of the concrete of bridge deckings has become a significant problem during the past decade. The annual cost of repairing such bridge deckings is about 70 million dollars.

The major portion of the early deterioration of concrete bridge decks has been attributed to the corrosion of steel reinforcing bars embedded in the concrete, which causes delamination and subsequent spalling of the concrete. Normally, reinforcing steel is passive towards corrosion in a basic environment as provided by concrete. This passivity, however, is destroyed by the presence of chloride ions and active corrosion takes place.

Presently, the two mostly used de-icing agents on highways and bridges are sodium chloride and calcium chloride. These de-icing agents when dissolved in water are able to penetrate the concrete decks, thus, leading to corrosion of steel reinforcement and subsequent cracking and spalling of the concrete. In the past decade, the amounts of sodium chloride and calcium chloride used as de-icing agents has increased multi-fold.

A reasonable method to prevent the corrosion of the steel reinforcing bars is by coating them with a barrier-type protective coating. It is felt that epoxy systems are the most promising coatings for this application.

5. Objectives

To investigate the feasibility of using epoxy systems to protect steel reinforcing bars and to select the epoxy systems that provide the best protection. The selection will be based on physiochemical testing with consideration given to economics involved in coating and fabricating of reinforcement.

6. Progress

The work in the first quarter primarily consisted of (1) attaining an overall view of epoxies, their chemical and physical properties and the feasibility of using them to protect steel reinforcing bars from the accelerated corrosive attack caused by chlorides from de-icing salts used on bridge decking. This was accomplished by a thorough literature search, discussions with experienced researchers and contact with epoxy manufacturers, formulators and applicators; (2) ascertaining what appropriate epoxy systems are commercially available; (3) the preliminary selection of promising epoxy systems; (4) consideration of existing methods of test applicable to various phases of this project and the development of new test methods, when necessary; (5) investigation of methods and techniques for applying protective coatings; (6) determining what surface condition of the steel reinforcing bars is necessary to obtain a sound protective coating.

The names and addresses of prospective epoxy manufacturers and formulators were obtained by consulting the Thomas Register and by reviews of such journals as Corrosion Abstracts, Corrosion, and Materials Performance and Protection, and by consulting with members of the National Bureau of Standards staff and the staffs of other organizations. The epoxy manufacturers and formulators contacted by letter, inquiring if they have epoxy coatings applicable to the present project, are listed in Table 1 along with comments regarding the nature of their replies and products. Six firms were visited by the NBS staff assigned to this project and the firms are listed in Table 2. Twenty of the firms given in Table 1 have replied to the initial inquiry. Three of those who replied stated that they had no materials suitable for the protection of steel reinforcing bars. Five firms, although advertised to handle epoxies, forwarded only information on non-epoxy systems. Altogether (Tables 1 and 2), 17 firms handling epoxy systems have been receptive to our contacts.

It has been decided to investigate only 100 percent solid epoxies, which can be either solids or liquids, as solvent containing coatings are highly susceptible to the formation of holidays necessitating the application of several coats. Furthermore, epoxy formulations with coal tars will not be studied since such formulations performed badly in reinforcing bar pull out tests [1/]. The epoxy floor covering materials do not appear to be very promising as protective coatings for reinforcing bars. To date 11 firms have been requested to submit samples for testing. Two samples have been received and the remaining samples will probably be received

during January 1972. It is still possible that other firms, including some not listed in Tables 1 and 2, may be requested to submit test samples in the near future.

For the purpose of simulating in-shop applications, the epoxy manufacturers or formulators that are willing to submit test samples are being requested to coat a few bars during a later portion of this project. Reinforcing bars were supplied by NBS to five of the firms visited for them to apply their coatings. These bars had different surfaces such as rust, mill scale and sandblasted surfaces, in order to determine what surface preparations will be necessary. At least one firm would not agree to application of their coatings to a surface which had not been sandblasted or pickled for mill scale and rust removal. The majority of firms stated that bars should be sandblasted for the best coating performance with pickling being the minimum surface preparation that is acceptable.

Other facets of the development of an epoxy system to coat reinforcing bars that have been considered are: (1) holiday detection; (2) determination of thickness of coatings; (3) application methods such as electrostatic spray, conventional air spray, hydraulic spray, dipping electrodeposition, and fluid beds; (4) site of application, in-situ or in-shop. Presently, in-shop application appears to be the most feasible method.

A general work plan-time schedule is presented in Table 3. In the following quarter's progress report more detailed schedule will be submitted. It is felt that the current work is progressing according to schedule.

7. Problems

A. Casting of Specimens for Pull-Out and Creep Testing

Wooden forms in which specimens for the pull-out and creep tests will be cast are being designed and will be fabricated at the National Bureau of Standards. It is felt the specimens should be cast with concrete having the same properties as that used in the current corrosion testing being carried out at the Fairbank Station of the Bureau of Public Roads. We are requesting, therefore, that the Bureau of Public Roads cast and cure the creep and pull-out specimens at the Fairbank Station using forms and reinforcing bars provided by the National Bureau of Standards. Control concrete cylinders cast along with the creep and pull-out specimens will be tested at NBS. Concrete proportions and method and time of mix should be provided to NBS.

B. Procurement and Logistics

As could be anticipated, the procurement of test samples is a slow process, however, it is hoped that most samples will be received by the end of January 1972. The logistics involved in shipping reinforcing bars, having them coated and returned will probably be time consuming and will be dependent on the speed of the applicator.

8. Work Planned for the Next Quarter

In the next quarter, the chemical resistance of cured epoxies, cast as discs, will be investigated in order to eliminate from further consideration any unacceptable systems. Disc specimens will be exposed to water, chloride and sulfate ion solutions,

aqueous saturated $Ca(OH)_2$ solution, steel, and cement paste and concrete. The permeability of thin films of epoxies to moisture and chloride ions will also be tested.

Corrosion testing of coated reinforcing bars toward chloride ions will be commenced. This will include such methods as visual inspection and electrochemical measurement.

The initial phases of pull-out and creep testing will be started. This includes the fabrication of specimen forms and setting-up of test equipment.

Some other aspects to be explored will be the feasibility of application of epoxy to reinforcing bars in-situ and the degree of surface preparation necessary for epoxies to adhere well to the steel reinforcing bars.

9. Acknowedgment

The contribution of Mr. Hugh F. Beeghly to this project is appreciated.

Reference

1. D. G. Moore, D. T, Klodt and R. J. Hensen, Protection of Steel in Prestressed Concrete Bridges, National Cooperative Highway Research Program Report 90, 1970.

TABLE 1. Epoxy Manufacturers and Formulators Contacted by Letter

		Comments
1.	Adhesive Engineering Company San Carlas, California	N.R.*
2.	Allied Finishing Specialities Company Chicago, Illinois	N.R.
3.	American Cyanamid Company Wallingford, Connecticut	N.R.
4.	American Bridge Division (U.S.Steel) Pittsburgh, Pennsylvania	N.R.
5.	Armour Industrial Products Company Chicago, Illinois	N.R.
6.	Armstrong Products Company, Inc. Warsaw, Indiana	Powdered epoxies, requested to coat reinforcing bars
7.	Ashland Chemical Company Columbus, Ohio	N.R.
8.	Atlas Minerals and Chemical Division Mertztown, Pennsylvania	Formulated epoxies for battery cases and flooring purposes
9.	Bartels Gordon Company Rockford, Illinois	Products are acrylic polymers
10.	B. F. Goodrich Industrial Products Company Akron, Ohio	N.R.

Table 1 - continued

		Comments
11.	Bisonite Company, Inc. Buffalo, New York	N.R.
12.	Carboline Company St. Louis, Missouri	With a reply sent a sample of a zinc metal-zinc silicate coating.
13.	Celanese Coating Company Jefferstown, Kentucky	Handles both 100% liquid and powder epoxies, agreed to provide samples. Requested to coat reinforcing bars.
14.	Chemical and Plastics Division Union Carbide Corporation New York, New York	N.R.
15.	Coating Products, Inc. Englewood, New Jersey	N.R.
16.	Dow Corning Corporation Midland, Michigan	N.R.
17.	E.I. DuPont de Nemours and Company, Inc. Wilmington, Delaware	N.R.
18.	Epoxylite Corporation South El Monte, California	N.R.
19.	Eastman Chemical Products, Inc. Kingsport, Tennessee	In reply, states that they have no appropriate epoxies

Table 1 - continued

		Comments
20.	Gates Engineering Division Wilmington, Delaware	Products are Neoprene and Hypalon and epoxies. Have been requested to submit sample and to coat reinforcing ba
21.	General Electric Company Plastics Department Pittsfield, Massachusetts	N.R.
22.	General Electric Company Silicone Products Division Waterford, New Jersey	N.R.
23.	General Mills Chemicals Minneapolis, Minnesota	100% solids polyamide epoxy liquid system. Samples have been received. Agreed to coat reinforcing bars
24.	H. B. Fuller Company St. Paul, Minnesota	100% solid epoxy liquid systems. Have agreed to provide samples. Requested to coat reinforcing bars
25.	James B. Sipe and Company Pittsburgh, Pennsylvania	N.R.
26.	Johns Manville Corporation Dutch Brand Division New York, New York	Asphalt membrane system
27.	Koppers Company Pittsburgh, Pennsylvania	Epoxy-coal tar systems
28.	Kordell Industries, Inc. Mishawaka, Indiana	N.R.

Table 1 - continued

		Comments
29.	Linatek Corporation of America Stafford Springs, Connecticut	N.R.
30.	Minnesota Mining and Manufacturing Adhesives Coatings and Sealers Division St. Paul, Minnesota	Forwarded samples of a one component epoxy system (cured epoxy dissolved in solvent)
31.	Monsanto Company St. Louis, Missouri	N.R.
32.	Narmco Materials Division Costa Mesa, California	Nitrite phenolic coating material
33.	PPG Industries, Inc. Coating and Resin Division Bloomfield, New Jersey	N.R.
34.	Permaflex Products Company, Inc. Philadelphia, Pennsylvania	Epoxy floor covering material
35.	Protective Coatings, Inc. Cleveland, Ohio	N.R.
36.	Protex-A-Cote, Inc. Newark, New Jersey	N.R.
37.	Robray Industries Verona, Pennsylvania	Applied powder coatings. Recommends their PVC coating. Has epoxy system. Agreed to coat reinforcing bars.

Table 1 - continued

		Comments
38.	Rowe Products, Inc. Niagara Falls, New York	Polyamide epoxy systems. Providing samples for testing. Agreed to coat reinforcing bars.
39.	The Ceilcote Company Berea, Ohio	Polyester tank lining coatings
40.	The Flintkote Company East Rutherford, New Jersey	In reply stated that they have no appropriate materials
41.	The Pfaudler Company Rochester, New York	In reply stated that they have no useful materials
42.	The Polymer Corporation Reading, Pennsylvania	N.R.
43.	The Topecoat Company, Inc. Evanston, Illinois	N.R.
44.	Wailes Dove Bitumastic Ltd. Hebburn, England	With reply sent a sample of a one component epoxy system (cured epoxy dissolved in solvent)
45.	Xylos Rubber Company Akron, Ohio	N.R.

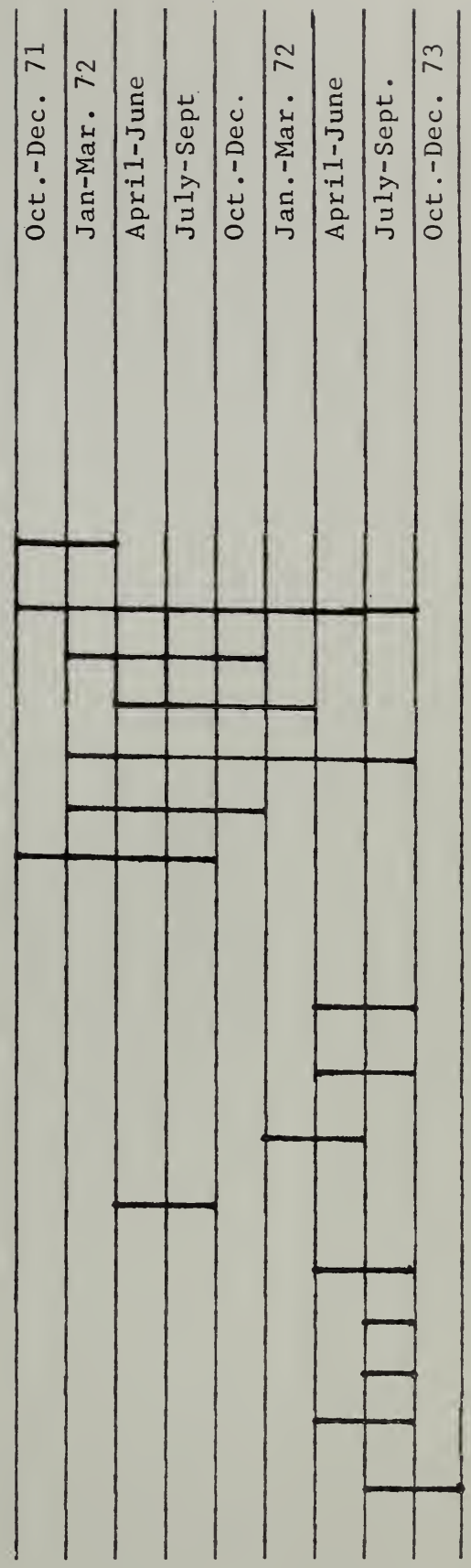
* N.R. denotes no reply to initial inquiry

TABLE 2 Epoxy Manufacturers, Formulators, and Applicators Visited by NBS Staff

		Comments
1.	H.C. Price Company Philadelphia, Pennsylvania	Applies powder epoxies to pipes by an automated line. Produces holiday detectors to locate pin holes in coatings.
2.	CIBA Tom's River, New Jersey	Epoxy resin manufacturer. Left bars to be coated. Will advise what epoxy systems they feel will adequately protect bars and will forward test samples of epoxies.
3.	SIKA Lyndhurst, New Jersey	Epoxy formulators, specializing in the concrete area. Left bars to be coated. In process of forwarding epoxy test samples.
4.	Shell Chemical Company Woodbury, New Jersey	Epoxy resin manufacturer. Left bars to be coated. Will provide epoxy test samples.
5.	Moboil Chemical Company Edison, New Jersey	Coating company. Left bars to be coated. Will provide epoxy test samples.
6.	Farboil Company Baltimore, Maryland	Epoxy applicators, especially powdered epoxies by electrostatic gun methods. Will coat reinforcing bars.

TABLE 3

GENERAL PROJECT SCHEDULE



1. Preliminary Selection of Coatings
2. Laboratory Tests
   - 2.1 Chemical Durability of Coatings
   - 2.2 Physical Properties of Coatings
   - 2.3 Physical Properties of Coated Bars
   - 2.4 Corrosion Properties
   - 2.5 Reinforcing Bar Properties
     - Temperature
     - Surface condition
3. Evaluation of Coatings
4. Evaluation of Coating Application Methods
5. Field and Placement Studies
6. Study Bar Fabricators Process
7. General Evaluation
   - 7.1 Coating Selections
   - 7.2 Coating Application & Bar Fabrication
   - 7.3 Cost Analysis
8. Reports

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